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LOCKHEED ELECTRONICS COMPANY, INC.

HOUSTON AEROSPACE SYSTEMS DIVISION

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TECHNICAL MEMORANDUM

FINAL REPORT ON ACTION DOCUMENT

63-0497-3715-05

"Quality of Signatures"

by

Edwin P.F. Kan

(NASA-CR-134263) QUALITY OF SIGNATURES

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Approved:

F.E. Alzofon, Supervisor,  
Measurement Analysis Section,  
Data Applications and Physics  
Department

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## SUMMARY

Three conclusions are drawn on the usability, inherent variations, and noise aspects of the spectral signatures processed from data collected by the Field Signature Acquisition System (FSAS). Future tasks of significance are also recommended.

This report closes the action document 63-0497-3715-05 entitled "Quality of Signatures". Conclusions from this work are based on the spectral data collected from winter wheat of the 1972/73 season, grown at Texas A&M University, College Station, Texas.

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## 1. OBJECTIVE OF ACTION DOCUMENT

Action Document 63-0497-3715-05, entitled "Quality of Signatures", has been designed to investigate spectral signatures processed from data collected by the Field Signature Acquisition System (FSAS). The three objectives of the Action Document are:

- (1) To study ways of reducing noise levels in the signatures.
- (2) To investigate the necessity of using other attributes to describe the signatures, e.g., using the shape of the signature curves.
- (3) To investigate data processing problems due to insufficient data.

## 2. SCOPE OF ACTION DOCUMENT

To accomplish the objectives of the Action Document, spectral data collected from winter wheat grown in the 1972/73 season was used for analysis. This set of FSAS data was collected during a field trip to Texas A&M University, College Station, Texas on April 10, 1973; the field trip was made under Action Document 63-0257-3333-32, dated April 3, 1973 to July 6, 1973. The growth stage of the investigated winter wheat was six (6) weeks away from harvesting.

Analysis activities were coordinated with C. Harlan and D. Loe; Harlan was the chief investigator for Action Document 63-0257-3333-32, and Loe was the programmer and analyst processing the FSAS data.

The present Action Document "Quality of Signatures" was initiated on December 5, 1973 and scheduled for a span of three (3) months. However, due to the impact of other projects of higher priority requested by NASA/JSC in the same period, the author was only available to work on this Action Document for a small fraction of his time. Thus, only the first objective required of this Action Document was accomplished. Two other major conclusions on the quality of FSAS spectral signatures were also drawn from this effort, as stated in the following section.

### 3. MAJOR ACCOMPLISHMENTS AND CONCLUSIONS

On analyzing the winter wheat data made available to this author, three conclusions were drawn concerning the quality of the spectral signatures collected by the FSAS system:

- (1) A smoothing process can be used to effectively reduce noise levels in FSAS signatures, and thus improve the quality of these signatures.
- (2) The violet and blue portions (spectral wavelength between 0.4 and 0.55 micron) of the signatures are unreliable, and should not be used for analysis.
- (3) Inherent instrument variations often cause fluctuations in signature values of as much as 0.05 units in a scale of 0 to 1.0. Such information is vital in analyzing FSAS signatures using clustering procedures such as the JSC program ISOCLS.

Appendices A, B, and C explain how these conclusions are derived.

#### 4. RECOMMENDATIONS FOR FUTURE WORK

The following work is recommended for future investigations on FSAS spectral data:

- (1) Identification of the relationship between signatures obtained by FSAS and signatures obtained by airborne sensors---The ultimate use of FSAS signatures is to provide signature banks for classification studies on data collected by airborne sensors. Thus, it is imperative to find out how FSAS signatures can be translated into signatures as seen by airborne sensors.
- (2) Discriminability studies between signatures of different features---Signatures other than those of winter wheat should be procured in order to study the separability between different features. Such studies will also afford further opportunities to determine whether or not additional attributes need to be employed to describe features, e.g., using the shape of signature curves.

## APPENDIX A

### A SMOOTHING PROCESS TO REDUCE NOISE LEVELS IN FSAS SIGNATURES

The following smoothing process was used on the wheat data and found to be of practical use: Figure A-1 and A-2 show the spectral signatures, smoothed and unsmoothed respectively; Figure A-3 and A-4 show the target/panel radiance readings, smoothed and unsmoothed respectively. Refer to Appendix D for notations and for a discussion on the process of obtaining spectral signatures from FSAS data.

- (1) Obtain smoothed target radiance readings  $\hat{x}_1, \hat{x}_2, \dots, \hat{x}_{1024}$  from the unsmoothed target radiance readings  $x_1, x_2, \dots, x_{1024}$ , where

$$\hat{x}_i = \frac{1}{5} (x_{i-2} + x_{i-1} + x_i + x_{i+1} + x_{i+2})$$

- (2) Obtain smoothed panel radiance readings  $\hat{y}_1, \hat{y}_2, \dots, \hat{y}_{1024}$  from the unsmoothed panel radiance readings  $y_1, y_2, \dots, y_{1024}$ , where

$$\hat{y}_i = \frac{1}{5} (y_{i-2} + y_{i-1} + y_i + y_{i+1} + y_{i+2})$$

- (3) Obtain smoothed spectral signature values  $\hat{z}_1, \hat{z}_2, \dots, \hat{z}_{1024}$  by ratioing the smoothed target readings  $\hat{x}_i$  to the smoothed panel readings  $\hat{y}_i$ . That is

$$\hat{z}_i = \hat{x}_i / \hat{y}_i$$



### Observations

This process was found to be able to eliminate undesirable spikes in the unsmoothed signatures, while the "main information" in the signatures is still conserved. This is apparent upon comparing Figure A-1 to Figure A-2.

Other similar smoothing algorithms can be designed and employed effectively, as long as the smoothing process does not suppress the "main information", especially the "high frequency" components in the readings curves. Formulation of the "information contents" and the "frequency components" in FSAS data, and a study of the consequences of a smoothing process, can be pursued along the lines of digital filtering theory, but are out of the scope of this report.

### Conclusion

A smoothing process such as that described above could be employed effectively to reduce noise levels in spectral signatures obtained from FSAS data.

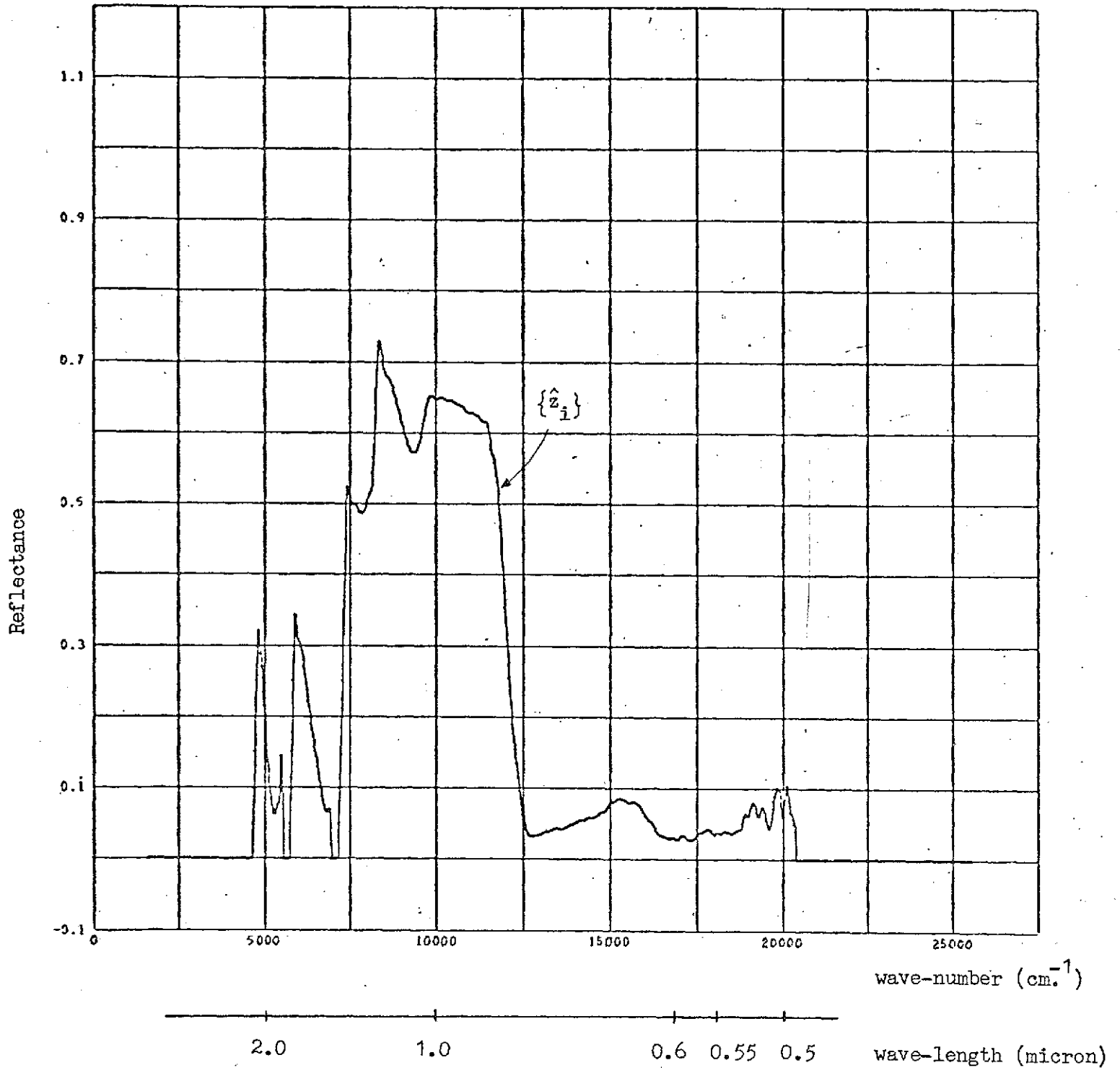


FIGURE A-1

Smoothed spectral signature of winter wheat,  $\{\hat{z}\}$ , as processed from the smoothed target/panel radiance readings  $\{\hat{x}_i\}/\{\hat{y}_i\}$  of Figure A-3.

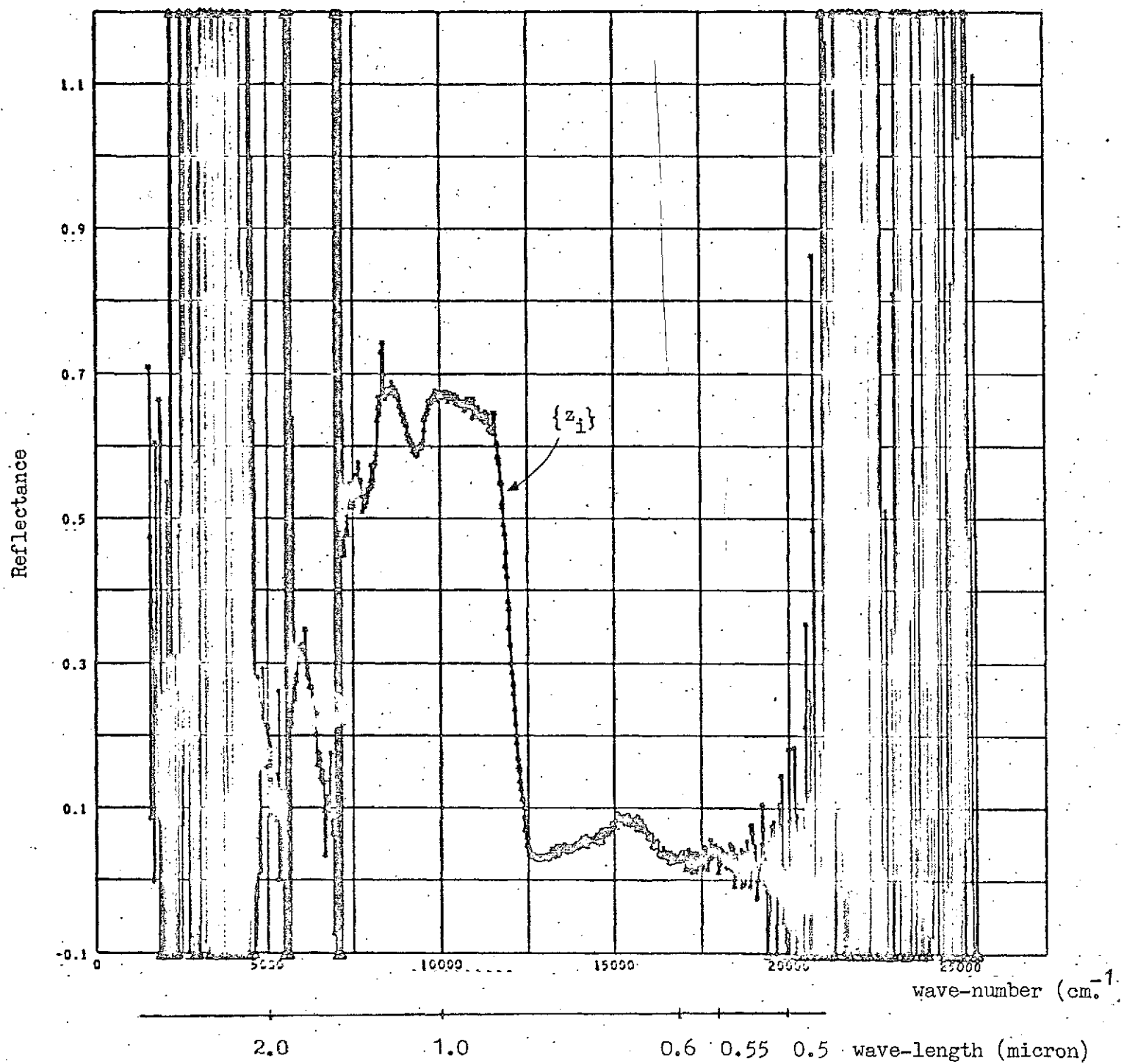


FIGURE A-2

Unsmoothed spectral signature of winter wheat,  $\{z_i\}$ , as processed from the unsmoothed target/panel radiance readings  $\{x_i\}/\{y_i\}$  of Figure A-4.

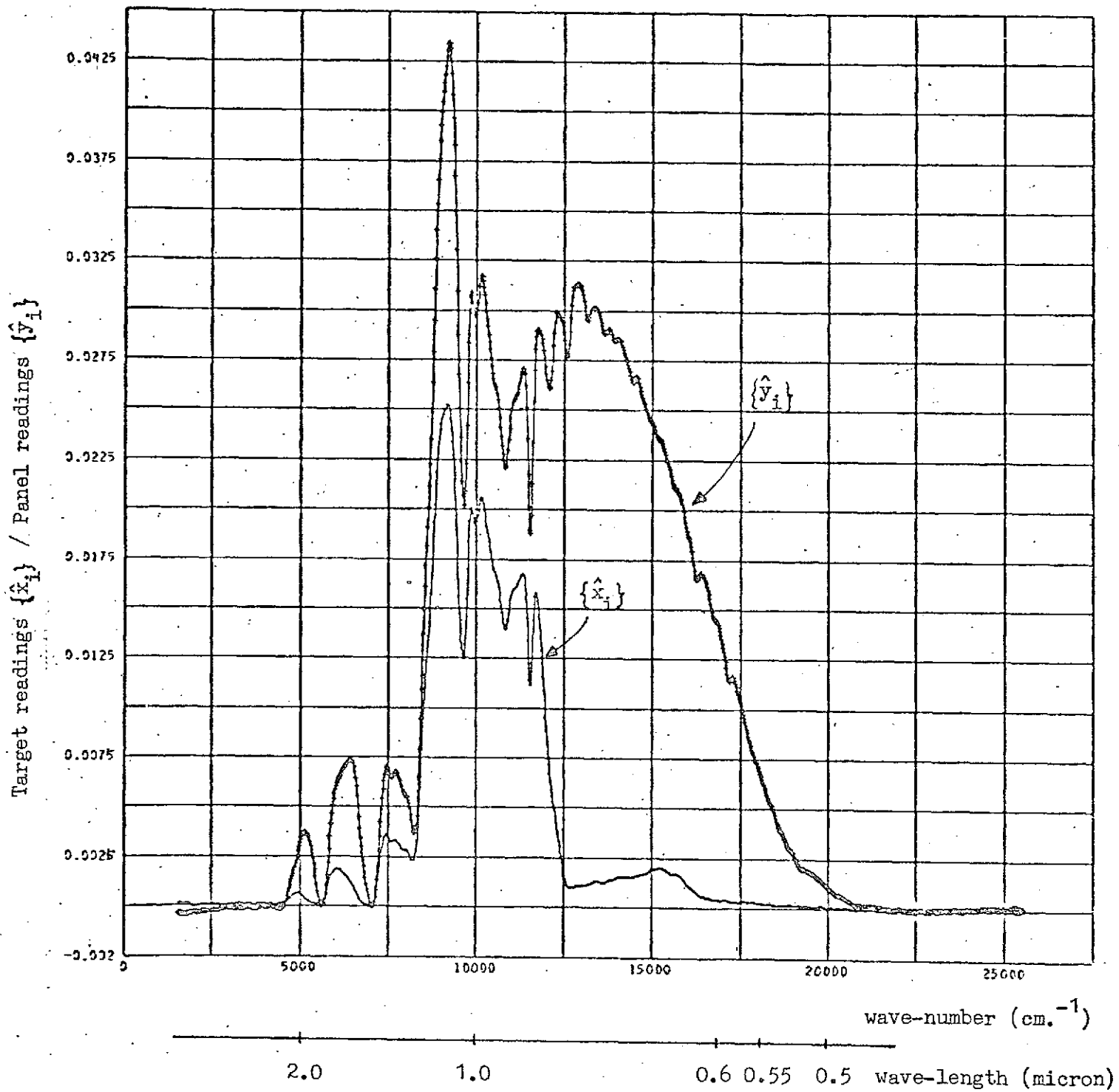


FIGURE A-3

Smoothed radiance readings of target (i.e., winter wheat),  $\{\hat{x}_i\}$ , and of panel (a highly reflective diffused reflector),  $\{\hat{y}_i\}$ .  $\{\hat{x}_i\}/\{\hat{y}_i\}$  are processed from the unsmoothed readings  $\{x_i\}/\{y_i\}$  of Figure A-4.

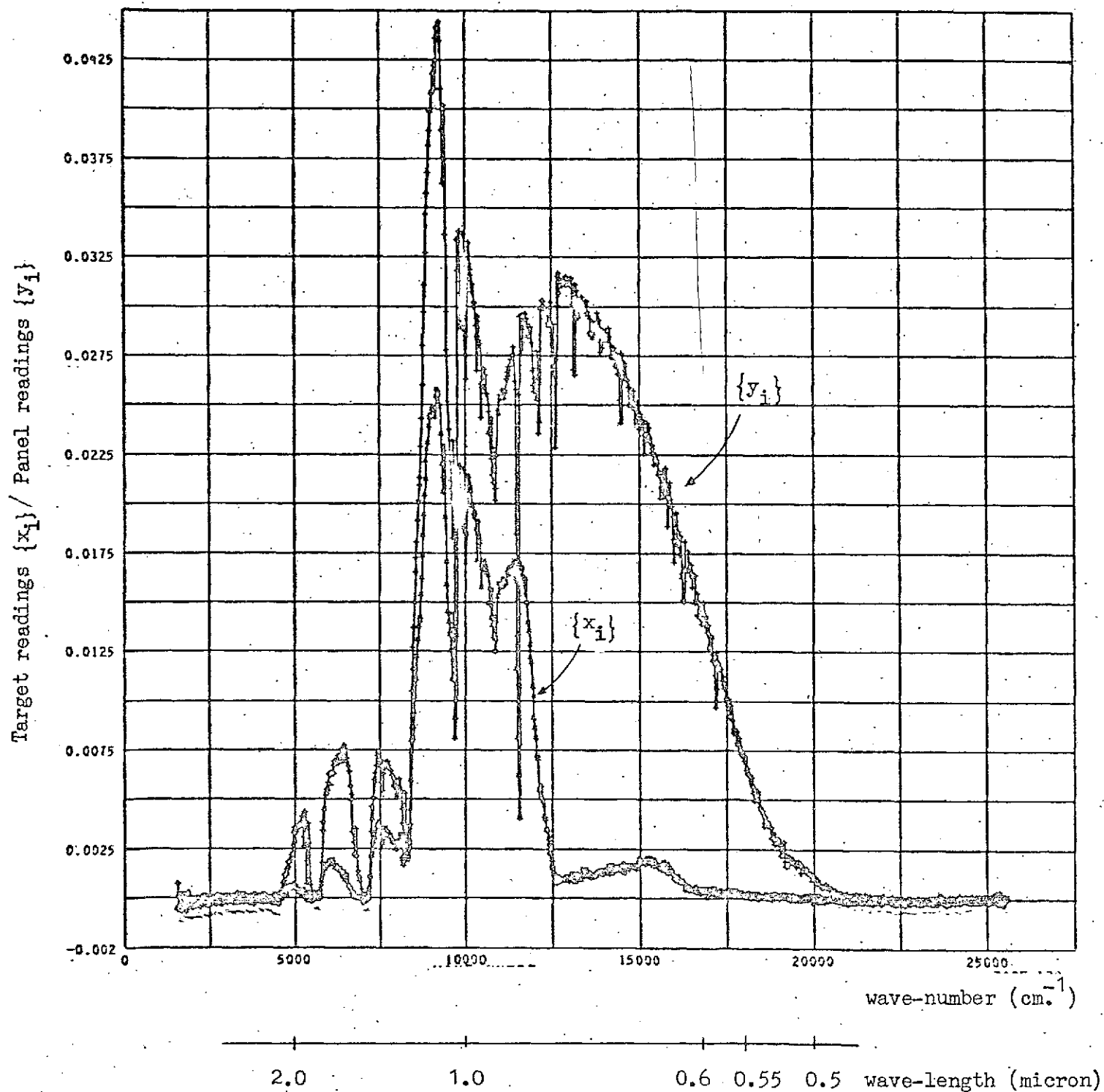


FIGURE A-4

Unsmoothed radiance readings of target (i.e., winter wheat),  $\{x_i\}$ ; and of panel (a highly reflective diffused reflector),  $\{y_i\}$ .  $\{x_i\} / \{y_i\}$  are obtained by the FSAS system.

## APPENDIX B

### REASONS WHY THE VIOLET AND BLUE PORTION OF FSAS SIGNATURES ARE UNRELIABLE

#### Assertion

The violet and blue portion (spectral wave-length between 0.4 and 0.55 micron) of FSAS signatures is unreliable.

#### Reasoning

This assertion is apparent from examining Figure A-2, which is a typical unsmoothed FSAS signature. The reason why noise spikes are so dense and significant in this spectral portion (0.4 to 0.55 micron) is explained as follows:

The spectral signature  $z_i$  being generated from the target readings  $x_i$  and the panel readings  $y_i$  by ratioing, i.e.,  $z_i = x_i/y_i$  (refer to Appendix D for a discussion of this process), the following equations show the deviation of the processed signature value  $z$  from its true value  $z_o$  when a deviation  $\Delta x$  occurs in the measurement of the true  $x_o$  and a deviation of  $\Delta y$  in the measurement of the true  $y_o$ :

$$\text{Measured target reading} = x = x_o + \Delta x$$

$$\text{Measured panel reading} = y = y_o + \Delta y$$

$$\text{True signature value} = z_o = x_o/y_o$$

$$\text{Processed signature value} = z = x/y$$

$$\begin{aligned} &= \frac{x_o + \Delta x}{y_o + \Delta y} \\ &= (\text{true signature value}) \left[ \frac{1 + \frac{\Delta x}{x_o}}{1 + \frac{\Delta y}{y_o}} \right] \quad (B1) \end{aligned}$$

In the spectral interval 0.5 - 0.55 micron (blue region of the spectrum),  $\Delta y \ll y_0$ ;  $\Delta y$  (and  $\Delta x$ ) being instrument variations. Thus, equation (B1) can be approximated as

$$z \simeq z_0 + \left( \frac{\Delta x}{x_0} \right) z_0$$

In the same spectral interval,  $x_0$  is small and is of the same order of magnitude of  $\Delta x$  (this statement is generally true for FSAS measurements). Thus, the signature value  $z$  in the blue spectral interval has an error of the order of 100%, and is unacceptable by normal standards.

In the spectral interval between 0.4 and 0.5 micron (violet region),  $x$  and  $y$  are too small in magnitude to produce any meaningful ratio  $z$ , since the error in each observable is the same order as the quantity observed.

The above argument has explained why the unsmoothed FSAS signature (Figure A-2) is so noisy and thus unreliable in the violet and blue region (0.4 to 0.55 micron). Concerning the reliability of the smoothed signature exhibited in Figure A-1 in the same spectral region, it should be remembered that, in general, smoothed curves are special interpretations of the unsmoothed curves. While the unsmoothed signature values fluctuate so extremely in the violet and blue region, and while careful modeling of the noise effects and their removal have not been performed, the smoothed values in this spectral region are valid FSAS signatures

to the extent of the validity of the smoothing process used. Therefore data processing procedure validity should be established before any claims are made to a unique FSAS signature.



## APPENDIX C

### FLUCTUATION OF FSAS SIGNATURE VALUES DUE TO INSTRUMENT VARIATIONS

On analyzing the FSAS wheat data made available to this author, it is observed that repeated observation of the same target produces spectral signatures which have values that vary as much as 0.05 units in a scale of 0 to 1.0.

This type of information is vital to the proper usage and interpretation of the results from a clustering analysis on FSAS signatures. The JSC clustering computer program ISOCLS\* requires a value for the input parameter STDMAX, which governs the size of a nominal-sized cluster. To use ISOCLS to cluster FSAS signatures, a value of 0.02 for STDMAX is thus suggested.

\* Reference: E. P. Kan, "The JSC Clustering Program ISOCLS and Its Applications", Lockheed Electronics Company, Inc., Houston, Texas, Technical Report LEC-0483, July 1973.

## APPENDIX D

### THE PROCESS OF OBTAINING SPECTRAL SIGNATURES (% REFLECTANCE CURVES) FROM FSAS DATA

The FSAS system derives spectral signatures, i.e., per cent reflectance curves of physical targets in three steps:

- (1) Obtain radiance readings  $x_1, x_2, \dots, x_{1024}$  of physical target. Readings are approximately 23 wave-numbers apart from one another,  $x_1$  being at wave-number 1601 and  $x_{1024}$  at 25,600 where wave-number denotes  $10,000/\text{wave-length}$  (in micron).
- (2) Obtain radiance readings  $y_1, y_2, \dots, y_{1024}$  of a white (barium sulphate) panel, which represents a highly reflective diffused reflector. These 1024 readings are taken at the same wave-numbers as  $x_1, x_2, \dots, x_{1024}$ .
- (3) Obtain the spectral signature, i.e., per cent reflectance values of the physical target  $z_1, z_2, \dots, z_{1024}$ , by ratioing the target readings to the panel readings. That is

$$z_i = x_i / y_i.$$

The  $x_i, y_i$ , and  $z_i$  values for a winter wheat target are plotted in Figure A-2 and A-4. The plot of the  $z_i$  values constitutes the spectral signature of the target.